Cogeneration: Options to Calculate Facility-Specific Efficiency Values
California Air Resources Board (ARB): Climate Change Reporting

Efficiency Method for Allocating Emissions

Thermal Energy Allocation

$$E_H = \frac{H / e_H}{H / e_H + P / e_P} \times E_T$$

Electricity Allocation

$$E_P = E_T - E_H$$

Where:

E_H	=	Emissions allocated to thermal energy
H	=	Total thermal energy output
e_H	=	Efficiency of thermal energy production
P	=	Total electricity output
e_P	=	Efficiency of electricity generation
E_T	=	Total direct combustion emissions of the CHP unit
E_P	=	Emissions allocated to electricity production

Facility-Specific Efficiency Values

Option 1: California Cogeneration Council Modified Efficiency Method

Please see Attachment 1: *California Cogeneration Council (CCC) Analysis of Methods to Allocate Greenhouse Gas Emissions*. This spreadsheet is based on the high thermal and low thermal examples titled, *Cogeneration Facility Heat and Mass Balance GHG Implementation*. The results in Attachment 1 for the CCC Modified Efficiency Method were calculated using the equations below. According to the CCC, these equations work well for the High Thermal Example when allocating GHG emissions using the Efficiency Method. The equations do not work well for the Low Thermal Example.

Topping Cycle Plants Efficiency Values

Electricity Generation Efficiency

$$e_P = \frac{P}{F}$$

Thermal Energy Production Efficiency

$$e_H = \frac{H}{F - P}$$

Where:
e_P = Efficiency of Electricity Generation
P = Total Electricity Output
F = Total Fuel Input
e_H = Thermal Energy Efficiency
H = Total Thermal Energy Output

Option 2: ARB Revision Based on EPA's CHP Partnership
The U.S. EPA handout entitled *Efficiency Metrics for CHP Systems: Total System and Effective Electric Efficiencies* outlines equations to calculate total system efficiency and effective electric efficiency. A second option for calculating facility-specific efficiencies could be to use the U.S. EPA CHP efficiency metrics. The effective electric efficiency ($\mathcal{E}_{EE}$) value could replace the efficiency of electricity generation (e_H) value referenced in the Efficiency Method for Allocating Emissions. Thermal energy production efficiency could be calculated using the total system efficiency as one of the inputs to the equation below.

Topping Cycle Plants Efficiency Values

Electricity Generation Efficiency

$$e_P = \mathcal{E}_{EE} = \frac{W_E}{Q_{FUEL} - \sum(Q_{TH}/\alpha)}$$

Thermal Energy Production Efficiency

$$e_H = \frac{\sum Q_{TH}}{n_O - \in_{EE}}$$

Option 3: Hybrid Approach
A third option could be a combination of using the CCC Modified Efficiency Method for high thermal production facilities and assigning a 2:1 thermal/electricity generation efficiency ratio to low thermal production facilities. Cogeneration facilities with high thermal energy production could use the CCC Modified Efficiency Method. Cogeneration facilities with low thermal energy generation could calculate the electricity generation efficiency following the CCC method and double that amount for the thermal energy production efficiency.

Option 4: Adopt the Registry Default Values
A fourth option could include ARB adoption of the California Climate Action Registry (Registry default values for thermal energy and electricity generation efficiency.

Option 5: Adopt Alternative Default Values
A fifth option could include ARB adoption of alternative default values different from the Registry adopted values.

Bottoming Cycle Plants Efficiency Values
A Bottoming Cycle Plant is a cogeneration facility that recovers steam or heat from a process stream to produce electricity. Depending on the recommended option, a similar approach adopted for Topping Cycle Plants be applied to Bottoming Cycle Plants.